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C O N F I D E N T I A L

INTERIM DEVELOPMENT REPORT #3

FOR

AN/URM-42(XN-1)

RADIO INTERFERENCE - FIELD INTENSITY

MEASURING EQUIPMENT

25 January 1954 through 30 April 1954

C O N F I D E N T I A L

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STODDART AIRCRAFT RADIO CO., INC.

6644 SANTA MONICA BOULEVARD • HOLLYWOOD 38, CALIFORNIA

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This Report Covers the Period 25 January 1954 through 30 April 1954

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STODDART AIRCRAFT RADIO COMPANY, INC.

6644 SANTA MONICA BOULEVARD - HOLLYWOOD 38, CALIFORNIA

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Contract Number NObsr-52589 1 May, 1954

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C O N F I D E N T I A L

ABSTRACT

This report covers the developmental work carried on during the period from 25 January 1954 through 30 April 1954 on Navy Contract NObsr-52589. This report is prepared in accordance with Military Specification MIL-R-978(SHIPS), "Reports and Microfilm: Research and Development".

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PART I

PURPOSE

The purpose of this project is the design, development, and production of five Radio Interference - Field Intensity Measuring Equipments for ultra- and super-high-frequency usage. These equipments are to be designated AN/URM-42(XN-1).

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GENERAL FACTUAL DATA

ENGINEERING PERSONNEL ASSIGNED TO THIS WORK.

1.	Donald Radmacher	Project Engineer
2.	Kendall Winborne	Project Engineer
3.	James Shaw	Assistant Project Engineer
4.	Henry Leknovich	Mechanical Designer
5.	Robert Pierce	Mechanical Designer
6.	George Buenger	Laboratory Assistant
7.	Leslie Freeman	Draftsman
8.	Sara Hathaway	Draftsman
9.	June La Vache	Draftsman
10.	Kenneth Mann	Draftsman
11.	Alexander Mc Adam	Technical Writer

DETAIL FACTUAL DATA

GENERAL:

The work summarized in this report includes partial calculation of the antenna factors for the three antennas chosen for use with the equipment, redesign of the impulse noise generator, and changes which are in process on redesign of the equipment mounting and carrying facilities; certain redesign has also been done on the 60 megacycle converter.

It is contemplated, at this time, that the next report will constitute the Final Development Report.

The following are included with this report:

Figure 1. Antenna AT-48/UP Aperture

Figure 2. URM-17 Input Circuits

Figure 3. Mixer Input Circuit

Figure 4. Modified Mixer Input Circuit

Figure 5. Impulse Noise Generator, Schematic Diagram

GOVERNMENT FURNISHED EQUIPMENT:

All tuning units to be utilized on this contract: 5 each: TN-128, TN-129B, TN-130, and TN-131 have been received and modified for use on this project.

In addition, two each of the following signal generators have been received:

TS-403/U
TS-419/U
TS-621/U
TS-622/U

The TS-419/U generators were apparently handled roughly during shipment since the klystron oscillator tubes had worked out of their sockets and bags of silica gel were broken open and the contents had been well distributed in the greasy dial gear trains.

ANTENNAS:

General. Three antennas were originally considered for the AN/URM-42(XN-1) equipment in order to adequately cover the frequency range of from 1 to 10 kmcs. These antennas are:

Antenna AT-49A/APR-4	1 kmc to 4 kmcs
Antenna AS-23/AP	1.55 kmc to 5.2 kmcs.
Antenna AT-48/UP	5.2 kmcs to 11 kmcs

Initially, these antennas were modified to the extent of providing a mounting rod on each antenna base to permit mounting in a tripod mast. These mountings are oriented in the mast by means of a simple keying mechanism in order that the directional characteristic of the antenna will coincide with the azimuth dial pointer and azimuth circle at the foot of the mast. This facilitates the taking of azimuth bearings on a received signal.

Originally, no provisions were made for orienting the antennas in the vertical plane. This condition is to be corrected in order that the antenna factors be based on orientation for maximum response to the signal source.

Antenna AT-48/UP: At microwave frequencies, the loss resistance in an antenna can be considered to be very small. For instance, assume that all the power abstracted from the passing wave by the antenna is delivered to the connected load. Then it can be shown* that

$$\text{Maximum Possible Received Power} = \frac{GE^2\lambda^2}{480\pi^2} \qquad (1)$$

where: G = power gain of antenna relative to an isotropic radiator
λ = wavelength
E = volts per unit length in same units that λ is expressed in.

This power can be considered as the power contained in a section of the wavefront having an area A and is found to have the value*

$$A = \frac{G\lambda^2}{4\pi} \qquad (2)$$

The area A is the effective absorption area and is generally less than the actual aperture area; typically 60 to 80 percent as great. A is expressed in the same units as λ. In determining the factors for this antenna, we will assume 70% efficiency.

* See "Electronic Measurements" by Terman & Pettit; pp 437

Combining formulae (1) and (2), we have:

$$W_1 = \frac{AE^2}{120\pi} \qquad (3)$$

Thus, we find that the power absorbed by the antenna is directly proportional to the aperture area A (so long as the larger aperture dimension is greater than a quarter wavelength) and independent of frequency.

The aperture area of Antenna AT-48/UP is rectangular in shape (see figure 1). Assuming 70% efficiency, the effective area in square meters is 0.0021.

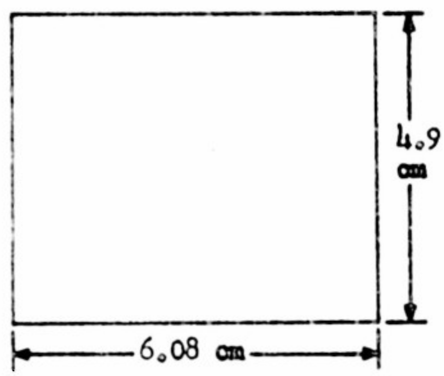

Figure 1. Antenna AT-48/UP Aperture

Using equation (3), the power delivered to the antenna load by a field intensity of one microvolt per meter is:

$$W_1 = \frac{0.0021\,(10^{-6})^2}{120\pi} = 5.57 \times 10^{-18} \text{ watts}$$

The voltage developed across the 50-ohm load by 5.57×10^{-18} watts is:

$$E = (W_1R)^{1/2} = (50 \times 5.57 \times 10^{-18})^{1/2}$$

$$= 16.7 \times 10^{-9} \text{ volts}$$

$$= 0.0167 \text{ microvolts}$$

The basic sensitivity of the AN/URM-42(XN-1) is 10 microvolts (the output meter scale is marked 1 to 100 microvolts, but the lowest attenuator setting has an X10 correcting factor). The antenna factor, therefore, will be:

$$K = \frac{10 \text{ uv (smallest output meter voltage unit)}}{0.0167 \text{ uv (voltage delivered by antenna from a 1 uv-per-meter field)}}$$

$$= 600$$

The AT-48/UP horn antenna has a nominal operating frequency coverage of 5000 to 6000 megacycles. The throat of the horn consists of a short section of 0.45 in. by 0.90 in. waveguide. The cutoff wavelength of a rectangular waveguide of these dimensions for the TE_{10} mode is

$$\lambda_c = 2a = 1.8 \text{ in.} = 4.57 \text{ cms}$$

$$= 6.5 \text{ kmcs}$$

This means that below 6.5 kmcs, the signal will be attenuated by the waveguide section and the antenna factor will rise above 600.

Antenna AS-23/AP: Factors cannot be computed for this antenna over its frequency range at this time. The antenna consists of an untuned dipole with a single, fixed-length, reflector element. The self-resonant frequency of the antenna as a half-wave dipole is approximately 3 kmcs. Approximate data can be derived by comparing this antenna with the other two antennas in the overlap region.

Antenna AT-49A/APR-4: The factor for the cone antenna can be derived in the same manner as was that for the horn antenna since the cone can be regarded as a type of horn when the sides of the cone are several wavelengths long. Cone antennas are broad-band devices which have a useful frequency coverage ratio of 10:1. The AT-49A/APR-4 was designed for a frequency range of 300 to 3000 megacycles with an input VSWR of less than 2. A cone antenna could be designed to cover the frequency range 1 kmc to 10 kmcs; however, its factor would be several times greater than that of the AT-48/UP horn antenna.

Aside from an increasing VSWR, the uppermost frequency of the cone antenna is determined by the radiation pattern. When the cone length (for a given frequency) β_l of a cone approaches 15, the radiation pattern in the vertical plane consists of so many lobes that proper orientation of the antenna is impossible. $\beta\ell$ for the AT-49A/APR-4 antenna at 4 kmcs is:

$$\beta = \frac{2\pi}{\lambda}\,\ell$$

where ℓ (length of cone side) is expressed in the same units as λ .

$$\beta\ell = \frac{2\pi \times 16.5 \text{ cms}}{7.5 \text{ cms}} = 13.8$$

The cone antenna factor will, of course, be derived on the basis of orientation for maximum response. We will assume the antenna loss resistance to be negligible. The cone input impedance at the base was designed for 78 ohms; however, we will assume the 78-to-50 ohm taper to be efficient and that all the power extracted from the passing wave by the antenna to be delivered to the connected load.

The basic sensitivity of the AN/URM-42(XN-1) is 10 microvolts; the smallest output meter indication represents 10 microvolts. The power required to develop 10 microvolts across the input impedance to the AN/URM-42(XN-1) is:

$$W = \frac{E^2}{R} = \frac{(10 \times 10^{-6})^2}{50}$$

$$= 2 \times 10^{-12} \text{ watts}$$

This is the power that must be delivered by the antenna to the r-f input in order to cause a 1 microvolt deflection of the output meter in the X10 position of the attenuator switch (straight-through section). The field intensity in microvolts-per-meter required to provide this power can be determined from the equation:

$$W = \frac{AE^2}{120\pi} \qquad (3)$$

$$2 \times 10^{-12} = \frac{AE^2}{120\pi}$$

$$E^2 = \frac{120\pi\,(2 \times 10^{-12})}{A}$$

$$E = \frac{(757 \times 10^{-12})^{1/2}}{\sqrt{A}} \text{ microvolts/meter} \qquad (4)$$

The ratio of E in microvolts-per-meter to the smallest output meter voltage unit will be the antenna factor K.

$$K = \frac{E\ uv}{10\ uv}$$

Repeating formula (2),

$$A = \frac{G\lambda^2}{4\pi} \qquad (2)$$

we see that the antenna effective absorption area is dependent on wave-length and on the power gain G (directivity). The directivity can be obtained from the antenna radiation pattern and is

$$G = \frac{\text{Maximum Radiation Intensity}}{\text{Average Radiation Intensity}}$$

The radiation pattern of a cone antenna varies considerably over its frequency range. Therefore, the antenna factor will vary accordingly. We are in the process of acquiring radiation patterns from which directivity data can be obtained. Actual calculation of the cone factor, then, must await receipt of this data from the manufacturer.

60-MEGACYCLE CONVERTER:

Undesired signal attenuation was discovered in the input circuits to the modified URM-17 portion of the AN/URM-42(XN-1) equipment. See figure 2.

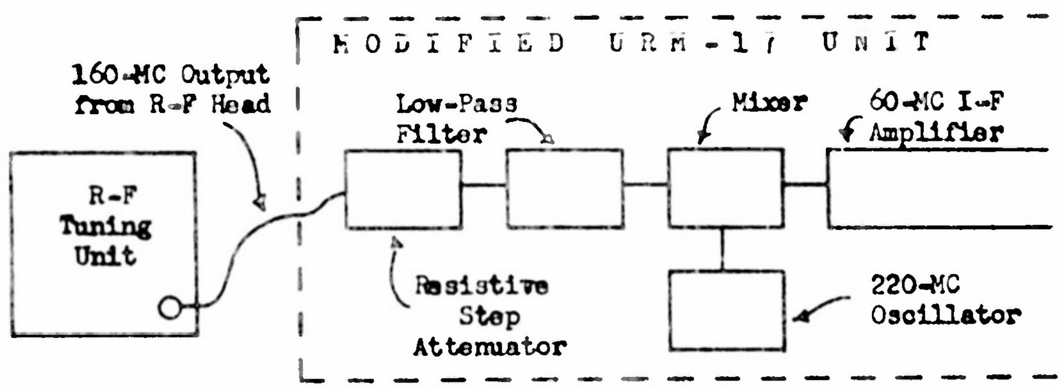

Figure 2. URM-17 Input Circuits

For proper operation of the attenuator, it is important that it be loaded with its own characteristic impedance of 50 ohms. The input impedance of the mixer circuit at point X (see figure 3) was measured, using a Hewlett Packard Model 803A Very-High-Frequency Impedance Bridge. The impedance was found to be equal to 60 + j12 at 160 megacycles.

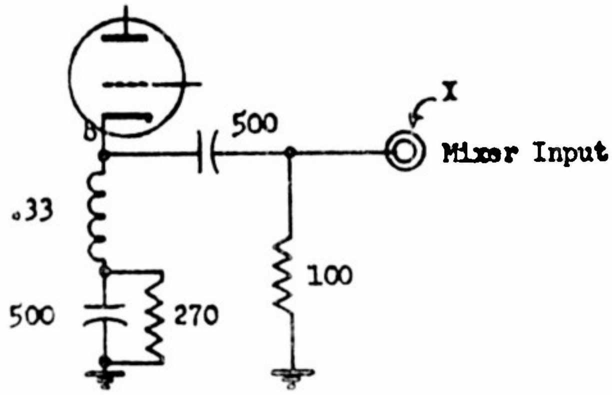

Figure 3. Mixer Input Circuit

This impedance was deemed unnecessarily high and the mixer input circuitry was modified (see figure 4). The input impedance of the mixer, as measured as point X of the modified circuit is now equal to 48 + j8. This impedance is equivalent to a VSWR of 1.16 and is thought to be entirely satisfactory.

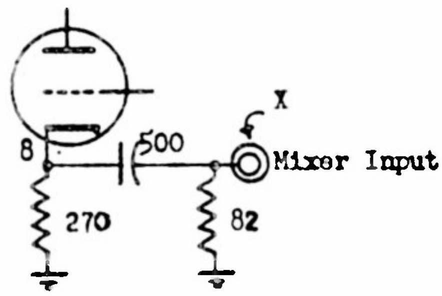

Figure 4. Modified Mixer Input Circuit

IMPULSE NOISE GENERATOR:

A change has been effected in the magnetic drive circuits of the Impulse Noise Generator. The transistor and push-pull amplifier has been replaced with a dual-triode multivibrator circuit of conventional circuitry. This change resulted in lower cost, a smaller number of parts, and simplicity in circuit design. A schematic diagram of the new Impulse Noise Generator is contained in figure 5.

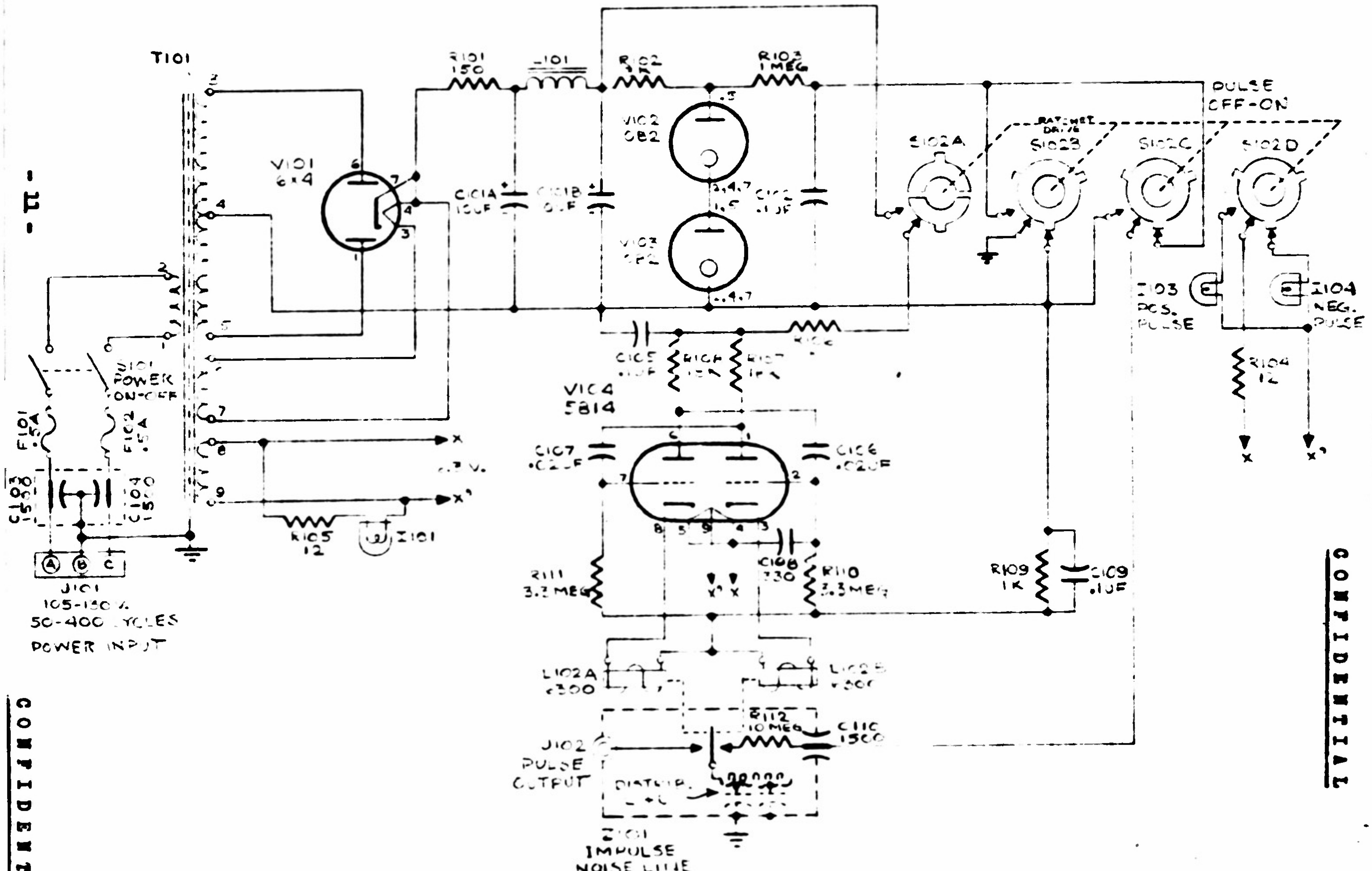

Figure 5. Impulse Noise Generator, Schematic Diagram

MOUNTING AND CARRYING FACILITIES:

After building the model of the AN/URM-42(XN-1) described in the report dated 15 November 1952, it became apparent that the main assembly of the equipment on a single mounting board was too heavy and excessively bulky.

After considerable thought, it has been decided to redesign the mounting and carrying facilities of the equipment. This work is now in progress. It is likely that the two power supplies will be carried in one case and a single tuning unit, the RI-FI Meter, and the Impulse Noise Generator in another case with the antennas and cables. A third case will probably contain the other three tuning units and possibly the tripod.

CONCLUSIONS:

Performance of the 60-megacycle converter has been highly satisfactory and no further time will be devoted to this circuit. Overall operation of the equipment is fast approaching design tolerances and figures and the major portions of the electronic circuitry can be considered final in their present form. More work, however, is contemplated on equipment mounting and carrying provisions as well as on antenna calculations and design.

PART 2

PROGRAM FOR NEXT INTERVAL:

Effort will be directed toward the completion of all design and construction work in the next period in order that the final phases of system testing can be completed and the equipment can be shipped at the earliest possible date.